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Associations between active living-oriented zoning and no adult leisure-time physical activity in the U.S.

Julien Leider [a,*], Jamie F. Chriqui [a,b], Emily Thrun [a]

[a] Institute for Health Research and Policy, University of Illinois at Chicago, 1747 West Roosevelt Road, M/C 275, Chicago, IL 60608-1264, USA
[b] Division of Health Policy and Administration, School of Public Health, University of Illinois at Chicago, 1603 West Taylor Street, M/C 923, Chicago, IL 60612-4394, USA

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ABSTRACT

Nearly one-third of adults report no leisure-time physical activity (LTPA). Governmental and authoritative bodies recognize the role that community design through zoning code changes can play in enabling LTPA. This study examined the association between zoning and no adult LTPA in the U.S. This study was conducted between 2012 and 2016, with analyses occurring in 2015–2016. Zoning codes effective as of 2010 were compiled for jurisdictions located in the 495 most populous U.S. counties and were evaluated for pedestrian-oriented code reform zoning, 11 active living-oriented provisions (e.g., sidewalks, bike-pedestrian connectivity, mixed use, bike lanes) and a summated zoning scale (max = 12). Individual-level LTPA data were obtained from the 2012 CDC Behavioral Risk Factor Surveillance System (BRFSS). County-aggregated, population-weighted zoning variables were constructed for linking to BRFSS. Log-log multivariate regressions (N = 147,517 adults), controlling for individual and county characteristics and with robust standard errors clustered on county, were conducted to examine associations between zoning and no LTPA. Relative risks (RR) compared predicted lack of LTPA at 0% and 100% county-level population exposure to each zoning predictor. Zoning code reforms were associated with a 13% lower probability of no LTPA (RR: 0.87, 95% CI: 0.82–0.92). Except for crosswalks, all zoning provisions were associated with an 11–16% lower probability of no LTPA. Having all 12 zoning provisions was associated with a 22% lower probability of no LTPA (RR: 0.78, 95% CI: 0.72–0.83). The results suggest that active living-oriented zoning is a policy lever available to communities seeking to reduce rates of no LTPA.

1. Introduction

Only one in five adults meet the *Physical Activity Guidelines for Americans* recommendations of achieving 150 min of physical activity (PA) per week or 30 min of at least moderate intensity PA daily (Centers for Disease Control and Prevention, 2016; U. S. Department of Health and Human Services, 2008). Moreover, 30% of adults report engaging in no leisure time PA (LTPA) (Office of Disease Prevention and Health Promotion, 2016b). Thus, identification of population-level strategies for reducing the prevalence of no LTPA is needed.

Research has shown that the built environment can facilitate or inhibit PA. For example, adults living in more walkable neighborhoods report engaging in up to 44.3 min per week of moderate intensity PA, compared to only 12.8 min per week in neighborhoods considered less walkable (Sallis et al., 2009). Similarly, more traditional neighborhood design with easy and close access to parks and playgrounds as well as more compact neighborhoods with dense street connectivity and mixed use (MU) developments are associated with increased activity (Berrigan and Troiano, 2002; Ewing et al., 2003; Frank and Engelke, 2001; Handy et al., 2002; Heath et al., 2006; Saelens et al., 2003; Sallis et al., 2015). In contrast, other features of the physical environment are associated with lower rates of PA and may inhibit PA, including the lack of pedestrian and bicycle facilities, inadequate accessibility of destinations, more sprawling communities, poor street/sidewalk connectivity, lack of sidewalks or bike paths, and single use zoning (Day, 2006; Ewing et al., 2003; Frank and Engelke, 2001; Handy et al., 2002; Saelens et al., 2003; Schilling and Mishkovsky, 2005; Slater et al., 2010).

In a recent *Preventive Medicine* commentary, Corburn delineated ways in which city planning can serve as "preventive medicine" (Corburn, 2015), as the built environment can support activity-friendly communities. Along these lines, several authoritative bodies and reports have recognized the role that community- and street-scale design can play in affecting the built environment and, ultimately, in supporting or inhibiting PA (Committee on Accelerating Progress in Obesity Prevention, 2012; Heath et al., 2006; National Physical Activity Plan Alliance, 2016; Office of Disease Prevention and Health

Abbreviations: ACS, American Community Survey; BMI, body mass index; BRFSS, Behavioral Risk Factor Surveillance System; GLM, generalized linear model; LTPA, leisure-time physical activity; MU, mixed use; PA, physical activity; RR, relative risk.

* Corresponding author.
E-mail addresses: jleide2@uic.edu (J. Leider), jchriqui@uic.edu (J.F. Chriqui), ethrun2@uic.edu (E. Thrun).

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Promotion, 2016a; U.S. Department of Health and Human Services, 2015).

The built environment is regulated at the county and municipal levels through the police powers delegated to the states under the 10th Amendment to the Constitution (Schilling and Linton, 2005; Schilling and Mishkovsky, 2005). While community design is driven largely by planning and land use design efforts, before design guidelines are established, zoning codes need to be written to authorize specific land uses (e.g., MU development) and to authorize or require features such as sidewalks and bike lanes (American Planning Association, 2006). In addition to taking a more active living-oriented approach to zoning, communities can elect to adopt more pedestrian-oriented zoning through new urbanist-type zoning reforms such as the SmartCode, form-based codes, and traditional neighborhood developments (Duany et al., 2005; Talen, 2006; Talen, 2013). Yet, zoning code reforms can face political challenges (Loh, 2012) due to the time and resources required to update zoning codes, lack of familiarity with code reform strategies, negative past experiences with zoning changes, or satisfaction with the current zoning system (Schilling and Mishkovsky, 2005). Conducting community outreach meetings, learning from other jurisdictions, forming an advisory committee, and engaging elected officials are effective strategies to overcome those obstacles (Schilling and Mishkovsky, 2005).

To our knowledge, only four studies have examined the relationship between zoning and community walkability and/or PA in the U.S. One study, conducted in California, found that MU zoning was associated with walking destinations (Cannon et al., 2013). In an earlier analysis conducted by the current study team using data for the 96 most populous U.S. counties, we found that active living-oriented zoning, including code reform zoning, was associated with increased odds of adult leisure time biking and/or walking (Chriqui et al., 2016b). Most recently, we found that code reform and active living-oriented zoning was positively associated with municipal-level adult active travel to work (Chriqui et al., 2016a), and that transit-oriented development zoning was positively associated with adult active travel to work and taking public transportation to work (Thrun et al., 2016). The current paper builds on this prior work by examining the association between active living-oriented zoning and no LTPA among adults in the U.S. Given the prior research, we hypothesized that more active living-oriented zoning would be associated with lower prevalence of no LTPA.

2. Methods

Zoning data were compiled between May 2012 and June 2015. Analyses were conducted between October 2015 and March 2016. The University of Illinois at Chicago (UIC) Institutional Review Board determined that this study did "not involve human subjects" (research protocol #2011-0880).

2.1. Study sample

The initial sample frame was based on the most populous 496 counties and 4 consolidated cities in the U.S., which contained 76.04% of the U.S. population according to 2010 Census population estimates. Since the zoning data were linked with the CDC's 2012 Behavioral Risk Factor Surveillance System (BRFSS) data, the frame was reduced by one Alaska county and by the four consolidated cities, which could not be linked to BRFSS. The resultant sample frame included 175,403 adult BRFSS respondents aged 18–64 residing in 495 of the most populous U.S. counties (Centers for Disease Control and Prevention, 2015). Of these individuals, 1588 were excluded because they were pregnant, and 26,298 were excluded because of missing data on: LTPA (645), income (17,240), body mass index (BMI) (5403), race/ethnicity (2191), and other controls including marital status, children in the home, education, and employment status (819). Excluded individuals were more likely to engage in no LTPA, have lower incomes, have slightly lower mean BMI, were more likely to be Hispanic and less likely to be white, more likely to be female, slightly younger, more likely to have never been married, less likely to have children in the home, less educated, and less likely to be employed. Since most missing data was on income and BMI, the final models were re-run both without individual income and without either individual income or BMI, while including all cases with data available for the other variables. The results from those models were very similar to those presented herein. The final analytic sample included 147,517 adults residing in 495 counties representing 75.16% of the U.S. population in 48 states and the District of Columbia.

2.2. Measures

2.2.1. Zoning predictors

This study involved the largest known undertaking to compile and evaluate zoning codes nationwide. Zoning codes are local policies or laws that divide a community into districts or zones that specify allowable uses, lot sizes, building bulk, and other developmental standards (Davidson and Dolnick, 2004). Due to resource constraints, we were unable to collect plans or separate design guidelines that also regulate land development.

Zoning codes effective as of 2010 were collected by Internet research with telephone and email verification to confirm adoption for all jurisdictions. The sample frame for zoning code collection included all 6821 municipal jurisdictions and unincorporated areas in the 495 counties containing the analytic sample. Due to grant resource limitations, the sample was restricted to the 4544 areas that represented >0.5% of their given county's population. This restriction only excluded areas with very small populations that collectively represented 2.10% of the 495 sample counties and 1.58% of the U.S. population. It was not possible to obtain 157 zoning codes due to them not being electronically available, the community's refusal to send a copy, and lack of response to follow-up calls; thus, the final set of zoning data covered 4387 municipal jurisdictions and unincorporated areas, representing 97.66% of the total population of the 495 counties. Most zoning codes which could not be obtained were for smaller jurisdictions that often noted the lack of resources to provide a copy of the code.

Detailed methods used to evaluate the zoning codes are described elsewhere (Chriqui et al., 2016a; Chriqui et al., 2016b). Zoning codes were assessed by urban planners and/or graduate-level urban planning students using the tool in Appendix A, with inter-coder agreement of at least 90%. A dichotomous (yes/no) variable captured whether each jurisdiction had adopted zoning code reforms. Additional dichotomous variables captured whether any of 11 specific active-living oriented zoning provisions [sidewalks; crosswalks; bike/pedestrian connectivity; street connectivity; bike lanes; bike parking; trails/paths; mixed use; active recreation (such as playgrounds or athletic fields); passive recreation (such as open space or parks); and other general walkability provisions (e.g., pedestrian plazas)] were addressed in any zone/district of each jurisdiction's zoning code. A summated active living zoning scale was created based on these 12 dichotomous measures. In order to link the zoning data to the BRFSS data (which only had county identifiers), county-aggregated, population-weighted zoning scores, ranging from 0 to 1, were created to measure the proportion of each county's population exposed to code reform zoning and each of the 11 active living measures. For example, if 60% of a given county's population was exposed to MU zoning at the municipal or unincorporated county area levels, the county-aggregated MU variable equaled 0.60. A county-aggregated zoning scale was also created based on the sum of the 12 measures, which ranged from 0 (none of the county population exposed to any of the 12 measures) to 1 (100% of the county population exposed to all 12 zoning measures).

2.2.2. No LTPA outcome and individual controls

Individual-level data on no LTPA and control data were obtained from the 2012 BRFSS, which has been found to reliable and substantially valid for the PA measures (Pierannunzi et al., 2013). BRFSS is an ongoing state-based telephone survey of noninstitutionalized civilian adults aged 18+ that includes self-reported data on health risk behaviors such as PA. BRFSS employs a multistage sampling design that incorporates both landlines and cellphones to produce a representative sample (Chowdhury et al., 2016). The dichotomous no LTPA outcome measure was derived from a "no" response to the BRFSS item asking: "During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?" Individual-level controls obtained from BRFSS are presented in Table 1. BMI was computed based on self-reported height and weight. BMI values <12 or >60 were treated as missing.

2.2.3. County control variables

County control variables were obtained from the American Community Survey (ACS) 2010–2014 5-year estimates, which are considered the most precise (U.S. Census Bureau, 2015). The 2010–2014 estimates were used

Table 1
Sample characteristics[a].

Variable	% or mean (SD)	Minimum[b]	Maximum[b]
Outcome			
No LTPA (%)	18.6 (38.9)		
Zoning provisions addressed (% except where noted)			
Code reform zoning	29.6 (34.2)	0	100
Sidewalks	70.3 (33.3)	0	100
Crosswalks	25.0 (30.8)	0	100
Bike-pedestrian connectivity	44.8 (37.0)	0	100
Street connectivity	40.7 (36.7)	0	100
Bike lanes	15.2 (27.4)	0	100
Bike parking	45.3 (38.5)	0	100
Bike-pedestrian trails/paths	61.3 (36.9)	0	100
Other walkability	69.0 (33.6)	0	100
Mixed use	69.2 (32.7)	0	100
Active recreation	80.0 (30.0)	0	100
Passive recreation	80.0 (30.0)	0	100
Active living zoning scale (mean)	0.5 (0.3)	0	1
Individual-level controls (% except where noted)			
Hispanic	9.0 (28.6)		
Race			
White (Ref)	76.8 (42.2)		
Black	12.1 (32.6)		
Asian	3.4 (18.1)		
Other race	7.7 (26.7)		
Female	55.8 (50.0)		
Age (mean)	45.8 (12.5)	18	64
Age squared (mean)	2257.6 (1090.7)	324	4096
Marital status			
Married (Ref)	54.2 (49.8)		
Never married	25.1 (43.3)		
Widowed/separated/divorced	20.7 (40.6)		
Child in the home	40.2 (49.0)		
Education			
Less than high school (Ref)	5.8 (23.4)		
High school	22.9 (42.0)		
Some college	27.6 (44.7)		
College	43.7 (49.6)		
Employed	69.6 (46.0)		
Income			
<$20,000 (Ref)	16.7 (37.3)		
$20,000–$24,999	7.3 (26.0)		
$25,000–$34,999	8.7 (28.1)		
$35,000–$49,999	12.7 (33.3)		
$50,000–$74,999	16.2 (36.9)		
>$75,000	38.4 (48.6)		
BMI (mean)	27.7 (6.1)	12.1	60.0
BMI squared (mean)	805.6 (383.7)	146.2	3600.0
BMI cubed (mean)	24,633.7 (19,686.2)	1767.2	216,000
County-level controls (% except where noted)			
Walkability scale (mean)	1.1 (0.9)	0.7	18.0
% households in poverty	13.2 (4.4)	3.5	31.4
% non-Hispanic white	64.6 (19.5)	3.6	95.5
% non-Hispanic black	12.0 (12.8)	0.3	69.8
% Hispanic	13.8 (13.2)	0.9	95.4
Median household income (mean)	59,678.7 (14,148.5)	30,581	123,966
Median age (mean)	37.2 (3.6)	24.5	56.9
South region	25.5 (43.6)		

[a] N = 147,517 adult 2012 BRFSS respondents in 495 counties representing 75.16% of the U.S. population in 48 states and the District of Columbia.
[b] Minimum and maximum are omitted for dichotomous (yes/no) variables.

so that 2012, the year of the outcome data, was the midpoint of the control data. County controls are also listed in Table 1. Included in the county controls was a county-level walkability scale that was created to control for the built environment using established methods (Ewing and Hamidi, 2014; Slater et al., 2010), based on ACS 2007–2011 data and NAVTEQ 2011 data available using ArcGIS version 9.1 software (ESRI, Redlands, California). The walkability scale, which was standardized and adjusted by a factor of one to reduce negative scale values, was based on four measures: the ratio of four-way intersections to all intersections (NAVTEQ), intersection density or the total number of intersections in the county divided by the county land area (NAVTEQ), housing unit density (ACS), and population density (ACS).

2.3. Statistical analysis

The zoning, BRFSS individual outcome and control, and county control data were linked using county geocodes. Separate multivariate log-log regressions computed as generalized linear models (GLMs) were conducted linking each zoning measure to the no LTPA outcome, controlling for the characteristics in Table 1. All models were clustered on county with robust standard errors. The results are presented as relative risks (RR) comparing 0 to 100% county-level population exposure to each of the active living-oriented zoning measures, or, in the case of the zoning scale, comparing 0 to 100% county-level exposure to all 12 zoning provisions. These RR compared the predicted probabilities of no LTPA for all individuals if there were 0% county-level zoning exposure to the

predicted probabilities of no LTPA for all individuals if there were 100% county-level zoning exposure. Confidence intervals for the RR were computed on the log scale before exponentiating the endpoints, and the associated *p*-values were computed from tests of whether the log RR was equal to zero. Because the study was restricted to 495 counties, all analyses used the unweighted BRFSS data. All analyses were conducted in Stata/SE version 13.1 (StataCorp LP, College Station, TX). Statistical significance was determined at the $p < 0.05$ level.

Model fit was compared for GLMs from the binomial family with the logit, probit, log-log, and complementary log-log links using the deviance statistic. Link tests of model specification were performed to verify model fit. The log-log models offered the best fit but failed the link test. As there were only two continuous individual-level controls, age and BMI, and a quadratic term for age was already included in the model while BMI was included without higher order terms, a cubic term for BMI was added to allow additional flexibility and improve model fit. With this modification, the log-log models no longer failed the link test. As a sensitivity check, multivariate logistic regressions were also computed, and the results were very similar to the log-log results shown herein.

3. Results

Table 1 presents the sample characteristics. About one-fifth of the sample (18.6%) engaged in no LTPA in the previous month, somewhat below the median BRFSS prevalence estimate of 23.1% for adults aged 18+ in all U.S. states and territories (Chowdhury et al., 2016). On average, individuals lived in counties where 29.6% of the population was exposed to code reform zoning. Average exposure to other active living-oriented zoning provisions ranged from 15–80%. Individuals were mostly non-Hispanic white, with slightly more females than males. More than half (54.2%) of the sample was married, while 40.2% had a child at home. The majority of individuals had at least some college education, and 70% were employed, while the majority had incomes of at least $50,000. On average, individuals were 46 years old and overweight. About a quarter (25.5%) of the sample lived in the South and, on average, individuals lived in counties that were predominantly non-Hispanic white, with median household incomes near $60,000, a median age of 37, and 13.2% of households in poverty.

Results of the adjusted regressions examining the association between county-level population exposure to code reform and active living-oriented zoning and no LPTA are presented in Table 2 (Appendix B presents all regression coefficients for each model). With the exception of crosswalks, all of the zoning measures were significantly associated with a reduced probability of no LTPA. For instance, living in a county where 100% of the population was exposed to code reform zoning was associated with a 13% lower probability of no LTPA compared to living in a county where none of the population was exposed to code reform zoning (RR: 0.87, 95% CI: 0.82–0.92). With the exception of zoning for crosswalks, exposure to individual active living-oriented zoning provisions was associated with an 11–16% lower probability of no LTPA. The result for the active living zoning scale indicates that living in a county where the entire population was exposed to all of the listed zoning provisions was associated with a 22% lower probability of no LTPA than living in a county where none of the population was exposed to any provisions (RR: 0.78, 95% CI: 0.72–0.83).

Table 2
Multivariate log-log regressions of no LTPA on code reform and active living-oriented zoning policy exposure[a].

Zoning provision addressed	RR[b] (95% CI)
Code reform zoning	0.87 (0.82–0.92)
Sidewalks	0.84 (0.80–0.88)
Crosswalks	0.96 (0.90–1.03)
Bike-pedestrian connectivity	0.89 (0.83–0.96)
Street connectivity	0.88 (0.83–0.93)
Bike lanes	0.86 (0.79–0.92)
Bike parking (proxy for street furniture)	0.85 (0.81–0.89)
Bike-pedestrian trails/paths	0.85 (0.81–0.89)
Other walkability (e.g., traffic calming, pedestrian plaza)	0.85 (0.81–0.90)
Mixed use	0.85 (0.81–0.89)
Active recreation	0.85 (0.80–0.90)
Passive recreation	0.85 (0.80–0.90)
Active living zoning scale	0.78 (0.72–0.83)

[a] Each row represents a separate regression model. All models controlled for the following individual characteristics: Hispanic ethnicity; black, Asian, or other race (white as referent); female; age, age squared; never married, widowed/separated/divorced (married as referent); child in the home; high school education, some college, college education (less than HS as referent); employed; income $20–24K, $25–34K, $35–49K, $50–74K, >$75K (<$20K as referent); BMI, BMI squared, and BMI cubed. All models controlled for the following county characteristics: walkability scale, % households in poverty, % non-Hispanic white, % non-Hispanic black, % Hispanic, median household income, median age, and South region. All models clustered on county with robust standard errors. N = 147,517 adult 2012 BRFSS respondents in 495 counties representing 75.16% of the U.S. population in 48 states and the District of Columbia.

[b] Relative risks (RR) compare 0 to 100% county-level exposure to the given zoning provision, or 0 to 100% county-level exposure to all zoning provisions in the case of the active living zoning scale.

4. Discussion

To our knowledge, this was the first study to examine the association of code reform and active living-oriented zoning with no LTPA. Consistent with our hypothesis, we found that code reform and active living-oriented zoning are associated with lower probability of no LTPA. This study builds upon the growing body of literature to examine the role that zoning can play as a population-based strategy for influencing the built environment and, ultimately, PA.

While zoning may take time to implement, it provides the necessary policy authorization to incorporate the active living-oriented provisions studied herein (e.g., parks and open space, connectivity, MU, bike lanes and parking, sidewalks, pedestrian plazas, etc.) and often requires such provisions in new developments and redevelopments (American Planning Association, 2006; Elliott et al., 2012). This study found that active living-oriented zoning is associated with a lower probability of no LTPA, which is consistent with our earlier study which found that more active living-oriented zoning was associated with increased odds of adult walking and/or biking (Chriqui et al., 2016b). The negative association between code reform zoning and no LTPA is also consistent with urban planning theory which posits that new urbanist (i.e., code reform) zoning is intended to create more pedestrian-oriented communities (Schilling and Linton, 2005; Talen, 1999, 2013). Similarly, the association between most of the active living-oriented zoning markers and lower probability of no LTPA was consistent with the literature which recommends community- and street-scale design as strategies for enabling or encouraging PA (Brennan Ramirez et al., 2006; Ewing et al., 2014; Frank and Engelke, 2001; Handy et al., 2002; Heath et al., 2006; Pucher et al., 2010; Sallis et al., 2015), although the literature, like this study, is primarily observational and correlational (Ferdinand et al., 2012; McCormack and Shiell, 2011).

It was somewhat unsurprising that zoning for crosswalks was not statistically associated with no LTPA given that crosswalks are a feature of the environment shown to facilitate children's active travel to school (Boarnet et al., 2005; McDonald et al., 2010) and older-adult PA (Chaudhury et al., 2012; Cheadle et al., 2010) (which was not studied herein) but less so for PA among adults aged 18–64 (McGinn et al., 2007; Sallis et al., 2015) who were the focus of this study. Older adults have different PA patterns due to age-related physiological changes, so they were excluded from this study (Chodzko-Zajko et al., 2009; Milanović et al., 2013). Future studies should explore the relationship between zoning and older adult activity.

4.1. Study limitations and strengths

The strengths of this study include the large, nationwide sample of adults in the 495 most populous U.S. counties, combined with zoning data covering 98% of these counties' populations. Additionally, focusing on no LPTA at the individual level made it possible to control for individual-level covariates. However, the findings are

subject to several limitations. First, as a cross-sectional study, causation cannot be inferred; future studies should examine the longitudinal influence of active living-oriented zoning on no LPTA so that endogeneity can be addressed to determine if zoning actually leads to more activity-friendly communities and, ultimately, more PA. Second, although we controlled for one measure of walkability, it was not sufficient for assessing zoning implementation through built environment changes; future studies should assess zoning implementation in practice. Third, data availability precluded allowing for a longer lag between the zoning measures and the no LTPA outcome (i.e., the last year that the BRFSS public use files included county geocodes was 2012). Although most of the zoning codes were adopted well before our 2010 cutoff, future studies should build in a longer lag to increase the likelihood of implementation. Fourth, the BRFSS data were based on self-reported PA; however, while self-reported data are typically deemed less reliable, that was less of a concern here given that our outcome measure, no LTPA, is less likely to lead to respondent bias (Pierannunzi et al., 2013), although population level results still need to be considered cautiously (Steene-Johannessen et al., 2016). Fifth, while this study relied on a large nationwide sample of individuals, the sample was not nationally representative, and the analyses could not employ sampling weights due to the restricted sample. Sixth, the sample was predominantly white and of high socioeconomic status. Racial/ethnic minorities are less likely to have access to recreation facilities or environmental conditions conducive for active transportation (Day, 2006; Sallis et al., 2012). Future studies should try to account for these disparities and obtain data on more diverse samples while considering the equity implications of active living-oriented zoning. And, finally, in order to link with BRFSS, the zoning measures were county-aggregated. While we were able to create a population-weighted measure of exposure to municipal and unincorporated area zoning within each county, it was not possible to link the individual respondents to their specific jurisdictions because BRFSS only provides county-level geocodes. Future studies should assess the risk of no LTPA among adults in the municipalities where they reside.

5. Conclusions

This study was the first to examine the relationship between active living-oriented zoning and no LTPA among adults residing in 495 of the most populous U.S. counties. This study demonstrates that active living-oriented zoning is associated with a significantly lower probability of no LTPA. Zoning is one of the key tools available to planners when designing communities to be more active living-oriented (Schilling and Linton, 2005). While zoning has to be implemented through changes to the built environment, it is a critical and necessary first step. Moreover, this study further supports urban planning theories and calls to action recognizing that community design and land use policies can create more pedestrian-friendly communities and, ultimately, more PA (Committee on Accelerating Progress in Obesity Prevention, 2012; National Physical Activity Plan Alliance, 2016; Talen, 2013; U.S. Department of Health and Human Services, 2015).

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Transparency document

The Transparency document associated with this article can be found, in the online version.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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References

American Planning Association, 2006. Planning and Urban Design Standards. John Wiley & Sons, Inc., Hoboken, NJ.
Berrigan, D., Troiano, R.P., 2002. The association between urban form and physical activity in U.S. adults. Am. J. Prev. Med. 23, 74–79.
Boarnet, M.G., Anderson, C.L., Day, K., McMillan, T., Alfonzo, M., 2005. Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. Am. J. Prev. Med. 28, 134–140.
Brennan Ramirez, L.K., Hoehner, C.M., Brownson, R.C., Cook, R., Orleans, C.T., Hollander, M., Barker, D.C., Bors, P., Ewing, R., et al., 2006. Indicators of activity-friendly communities: an evidence-based consensus process. Am. J. Prev. Med. 31, 515–524.
Cannon, C.L., Thomas, S., Treffers, R.D., Paschall, M.J., Heumann, L., Mann, G.W., Dunkell, D.O., Nauenberg, S., 2013. Testing the results of municipal mixed-use zoning ordinances: a novel methodological approach. J. Health Polit. Policy Law 38, 815–839.
Centers for Disease Control and Prevention, 2015. Behavioral Risk Factor Surveillance System (Available: http://www.cdc.gov/brfss/index.html).
Centers for Disease Control and Prevention, 2016. Facts about Physical Activity (Available: http://www.cdc.gov/physicalactivity/data/facts.htm).
Chaudhury, H., Mahmood, A., Michael, Y.L., Campo, M., Hay, K., 2012. The influence of neighborhood residential density, physical and social environments on older adults' physical activity: an exploratory study in two metropolitan areas. J. Aging Stud. 26, 35–43.
Cheadle, A., Egger, R., LoGerfo, J.P., Schwartz, S., Harris, J.R., 2010. Promoting sustainable community change in support of older adult physical activity: evaluation findings from the Southeast Seattle Senior Physical Activity Network (SESPAN). J. Urban Health 87, 67–75.
Chodzko-Zajko, W.J., Proctor, D.N., Fiatarone Singh, M.A., Minson, C.T., Nigg, C.R., Salem, G.J., Skinner, J.S., 2009. American College of Sports Medicine position stand. Exercise and physical activity for older adults. Med. Sci. Sports Exerc. 41, 1510–1530.
Chowdhury, P.P., Mawokomatanda, T., Xu, F., Gamble, S., Flegel, D., Pierannunzi, C., Garvin, W., Town, M., 2016. Surveillance for certain health behaviors, chronic diseases, and conditions, access to health care, and use of preventive health services among states and selected local areas - Behavioral Risk Factor Surveillance System, United States, 2012. Morbidity and Mortality Weekly Report. Surveillance Summaries (Washington, D.C.: 2002). 65, pp. 1–142.
Chriqui, J.F., Leider, J., Thrun, E., Nicholson, L.M., Slater, S., 2016a. Communities on the move: pedestrian-oriented zoning as a facilitator of adult active travel to work in the United States. Front. Public Health 4. http://dx.doi.org/10.3389/fpubh.2016.00071.
Chriqui, J.F., Nicholson, L.M., Leider, J., Slater, S.J., 2016b. More active living–oriented county and municipal zoning is associated with increased adult leisure time physical activity—United States, 2011. Environ. Behav. 48, 111–130. http://dx.doi.org/10.1177/0013916515611175.
Committee on Accelerating Progress in Obesity Prevention, 2012. In: Glickman, D., Parker, L., Sim, L.J., Del Valle Cook, H., Miller, E.A. (Eds.), Accelerating progress in obesity prevention: solving the weight of the nation. Institute of Medicine of the National Academies, Washington, DC.
Corburn, J., 2015. City planning as preventive medicine. Prev. Med. 77, 48–51.
Davidson, M., Dolnick, F., 2004. A Planner's Dictionary. American Planning Association, Chicago, IL.
Day, K., 2006. Active living and social justice: planning for physical activity in low-income, black, and Latino communities. J. Am. Plan. Assoc. 72, 88–99.
Duany, A., Sorien, S., Wright, W., 2005. SmartCode v. 9.2 (Available: http://transect.org/codes.html).
Elliott, D., Goebel, M., Meadows, C., 2012. The Rules that Shape Urban Form. American Planning Association, Chicago, IL.
Ewing, R., Hamidi, S., 2014. Measuring Urban Sprawl and Validating Sprawl Measures. National Institutes of Health and Smart Growth America, Washington, DC (Available: http://gis.cancer.gov/tools/urban-sprawl/sprawl-report-short.pdf).
Ewing, R., Meakins, G., Hamidi, S., Nelson, A.C., 2014. Relationship between urban sprawl and physical activity, obesity, and morbidity - update and refinement. Health Place 26, 118–126.
Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., Raudenbush, S., 2003. Relationship between urban sprawl and physical activity, obesity, and morbidity. Am. J. Health Promot. 18, 47–57.

Ferdinand, A.O., Sen, B., Rahurkar, S., Engler, S., Menachemi, N., 2012. The relationship between built environments and physical activity: a systematic review. Am. J. Public Health 102, e7–e13.
Frank, L.D., Engelke, P.O., 2001. The built environment and human activity patterns: exploring the impacts of urban form on public health. J. Plan. Lit. 16, 202–218.
Handy, S.L., Boarnet, M.G., Ewing, R., Killingsworth, R.E., 2002. How the built environment affects physical activity: views from urban planning. Am. J. Prev. Med. 23, 64–73.
Heath, G.W., Brownson, R.C., Kruger, J., Miles, R., Powell, K.E., Ramsey, L.T., Task Force on Community Preventive Services, 2006. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. J. Phys. Act. Health 3, S55–S76.
Loh, C.G., 2012. Four potential disconnects in the community planning process. J. Plan. Educ. Res. 32, 33–47.
McCormack, G.R., Shiell, A., 2011. In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Int. J. Behav. Nutr. Phys. Act. 8, 125.
McDonald, N.C., Deakin, E., Aalborg, A.E., 2010. Influence of the social environment on children's school travel. Prev. Med. 50 (Suppl. 1), S65–S68.
McGinn, A.P., Evenson, K.R., Herring, A.H., Huston, S.L., Rodriguez, D.A., 2007. Exploring associations between physical activity and perceived and objective measures of the built environment. J Urban Health 84, 162–184.
Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., James, N., 2013. Age-related decrease in physical activity and functional fitness among elderly men and women. Clin. Interv. Aging 8, 549–556.
National Physical Activity Plan Alliance, 2016. National Physical Activity Plan (Available: http://www.physicalactivityplan.org/docs/2016NPAP_Finalforwebsite.pdf).
Office of Disease Prevention and Health Promotion, 2016a. Healthy People 2020 Topics and Objectives: Physical Activity (Available: http://www.healthypeople.gov/2020/topics-objectives/topic/physical-activity/objectives).
Office of Disease Prevention and Health Promotion, 2016b. Physical Activity: Adults engaging in no leisure time phsyical activity (age adjusted, percent, 18+ years) (Available: http://www.healthypeople.gov/2020/data-search/Search-the-Data?&f[0]=field_topic_area%3A3504).
Pierannunzi, C., Hu, S.S., Balluz, L., 2013. A systematic review of publications assessing reliability and validity of the Behavioral Risk Factor Surveillance System (BRFSS), 2004–2011. BMC Med. Res. Methodol. 13, 49.
Pucher, J., Dill, J., Handy, S., 2010. Infrastructure, programs, and policies to increase bicycling: an international review. Prev. Med. 50 (Suppl. 1), S106–S125.
Saelens, B.E., Sallis, J.F., Frank, L.D., 2003. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Ann. Behav. Med. 25, 80–91.
Sallis, J.F., Floyd, M.F., Rodríguez, D.A., Saelens, B.E., 2012. Role of built environments in physical activity, obesity, and cardiovascular disease. Circulation 125, 729–737.
Sallis, J.F., Saelens, B.E., Frank, L.D., Conway, T.L., Slymen, D.J., Cain, K.L., Chapman, J.E., Kerr, J., 2009. Neighborhood built environment and income: examining multiple health outcomes. Soc. Sci. Med. 68, 1285–1293.
Sallis, J.F., Spoon, C., Cavill, N., Engelberg, J.K., Gebel, K., Parker, M., Thornton, C.M., Lou, D., Wilson, A.L., et al., 2015. Co-benefits of designing communities for active living: an exploration of literature. Int. J. Behav. Nutr. Phys. Act. 12, 30.
Schilling, J., Linton, L.S., 2005. The public health roots of zoning: in search of active living's legal genealogy. Am. J. Prev. Med. 28, 96–104.
Schilling, J., Mishkovsky, N., 2005. Creating a Regulatory Blueprint for Healthy Community Design: A Local Government Guide to Reforming Zoning and Land Development Codes. ICMA, Washington, D.C.
Slater, S.J., Ewing, R., Powell, L.M., Chaloupka, F.J., Johnston, L.D., O'Malley, P.M., 2010. The association between community physical activity settings and youth physical activity, obesity, and body mass index. J. Adolesc. Health 47, 496–503.
Steene-Johannessen, J., Anderssen, S.A., van der Ploeg, H.P., Hendriksen, I.J., Donnelly, A.E., Brage, S., Ekelund, U., 2016. Are self-report measures able to define individuals as physically active or inactive? Med. Sci. Sports Exerc. 48, 235–244.
Talen, E., 1999. Sense of community and neighbourhood form: an assessment of the social doctrine of New Urbanism. Urban Stud. 36, 1361–1379.
Talen, E., 2006. SmartCode Justice [The Transect]. Places. 18 pp. 30–35.
Talen, E., 2013. Zoning for and against sprawl: the case for form-based codes. J. Urban Des. 18, 175–200.
Thrun, E., Leider, J., Chriqui, J.F., 2016. Exploring the cross-sectional association between transit-oriented development zoning and active travel and transit usage in the United States, 2010–2014. Front. Public Health 4. http://dx.doi.org/10.3389/fpubh.2016.00113.
U. S. Department of Health and Human Services, 2008. 2008 Physical Activity Guidelines for Americans. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion, Washington, D.C.
U.S., Census Bureau, 2015. American Community Survey: When to Use 1-year, 3-year, or 5-year Estimates (Available: http://www.census.gov/programs-surveys/acs/guidance/estimates.html).
U.S. Department of Health and Human Services, 2015. Step It Up! The Surgeon General's Call to Action to Promote Walking and Walkable Communities. U.S. Department of Health and Human Services, Washington, D.C. (Available: http://www.surgeongeneral.gov/).